



# FASTRAC

## The University of Texas at Austin

2004 AMSAT- North America  
Space Symposium and Annual  
Meeting

*October 8<sup>th</sup>-13<sup>th</sup>, 2004*  
*Arlington, VA*

**Greg Holt, KE5BJC**

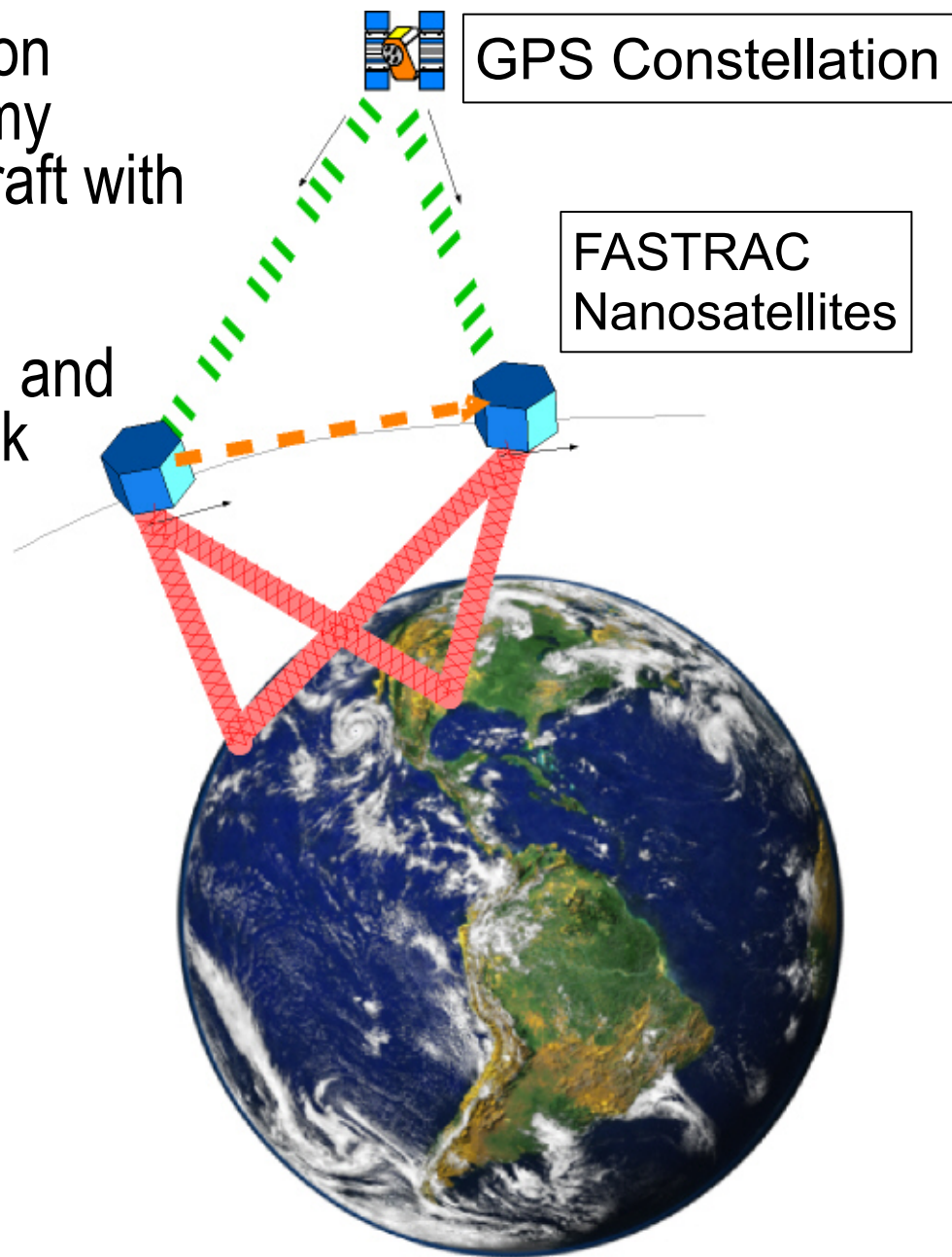
**Thomas Campbell,**  
**KD5TIO**

**Dr. E. Glenn Lightsey**

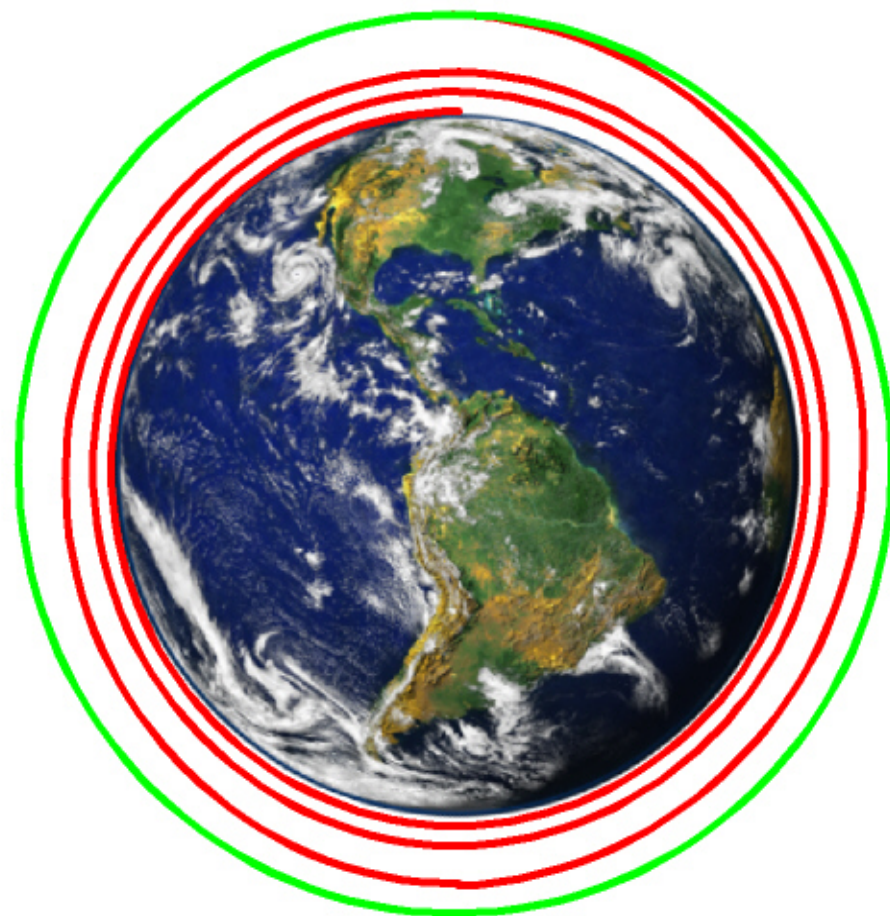


# Mission Operations Concept / Overview

Formation  
Autonomy  
Spacecraft with  
Thrust,  
RelNav,  
Attitude, and  
Crosslink



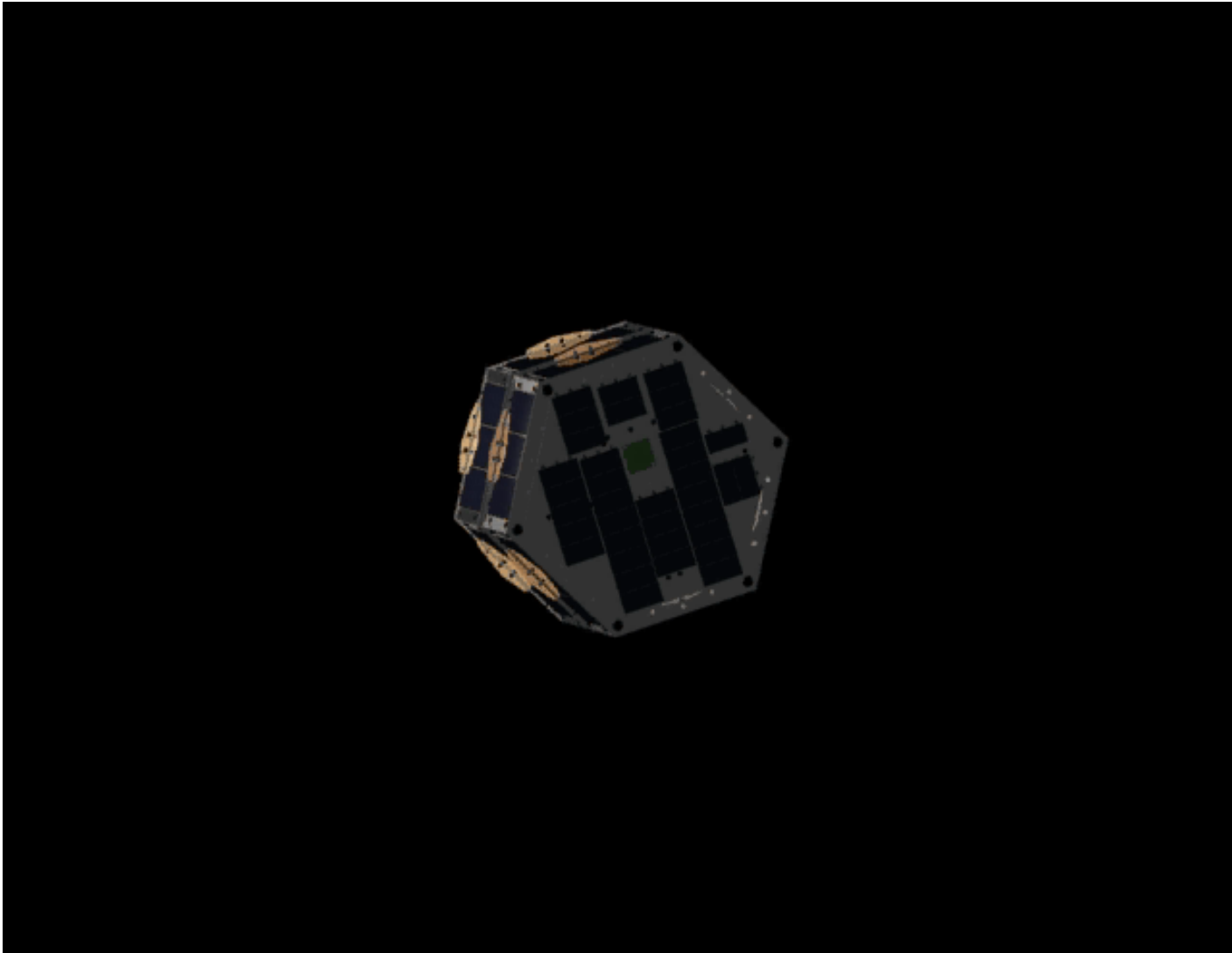
With Thruster  
Without Thruster





# FASTRAC Separation

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# Project Scope / Program Objectives

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## Mission Statement

The purpose of the FASTRAC mission is to investigate enabling technologies for satellite formations; these will include thrust, relative navigation, attitude, and crosslink. This will be achieved by taking data on orbit with a network of ground stations and processing the data for evaluation.

## Technology Demonstration

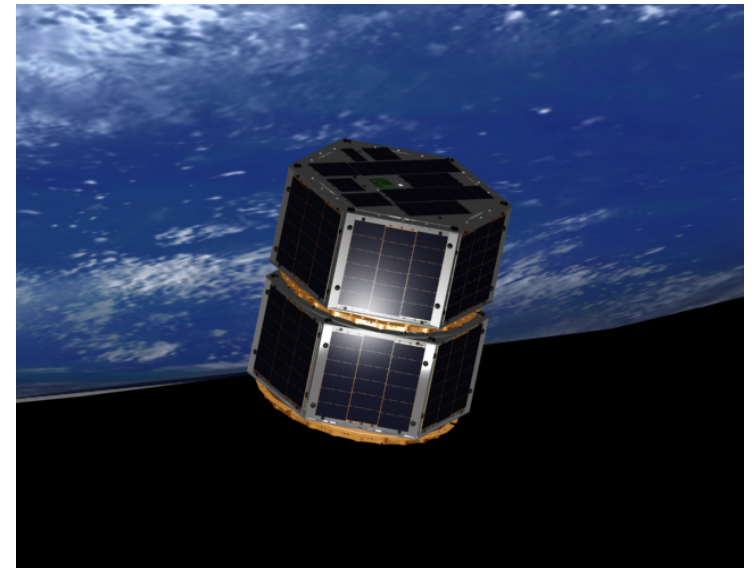
- GPS Relnav Solution via Real-Time Crosslink Data Exchange
- Distributed Ground Station Network
- Micro-discharge Plasma Thruster

## Mission Objectives

- Demonstrate GPS Relative Navigation
- Demonstrate Two-way Intersatellite Crosslink with verified data exchange
- Demonstrate Distributed Ground Station Network
- Demonstrate effectiveness of the Micro-discharge Plasma Thruster

## Mission Minimum Success Criterion

- Accomplish at Least One of the Mission Objectives







# Project Requirements

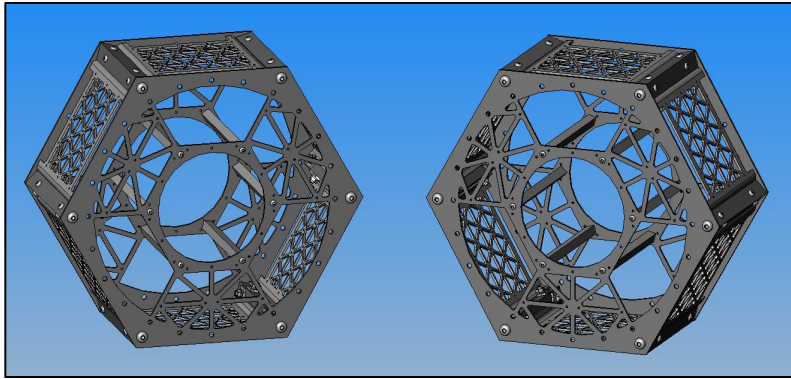
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## Mission Goals & Requirements

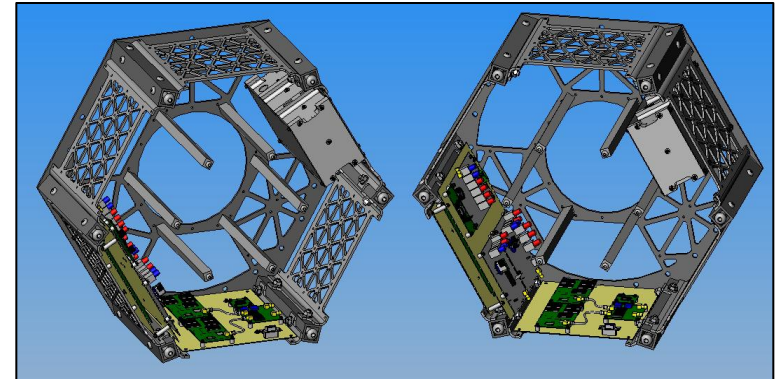
- Demonstrate realtime, on-orbit relnav GPS solution to an accuracy of  $\pm 1\text{km}$  versus post-processed solution
- Receipt of satellite data from both satellites by at least 2 ground stations, at least one of which is remotely commanded
- Extend the Life of one Vehicle by imparting an altitude separation between the two satellites  $\geq 5\%$  of their initial altitude
- Deliver EDU nanosatellite payload to AFRL in January 2005



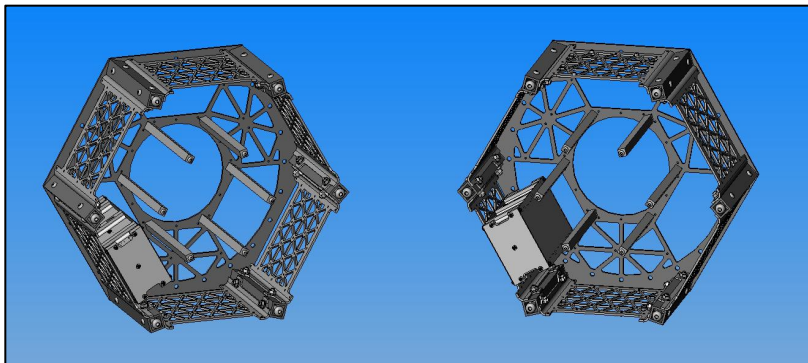
# Nanosatellite Integration Plan



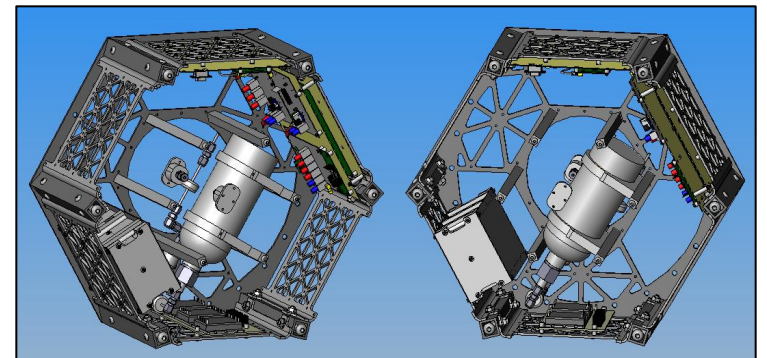
**1. Structures Assembled**



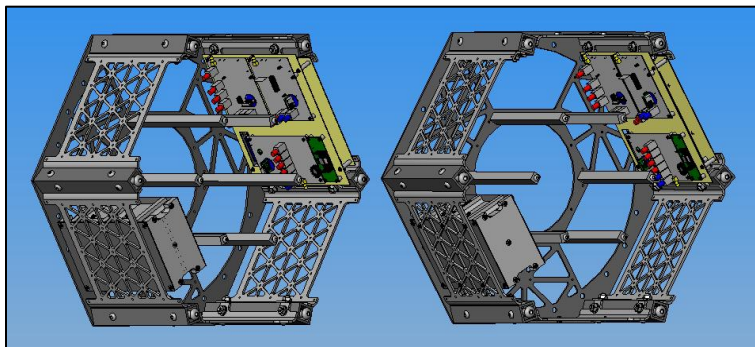
**4. GPS System Mounted**



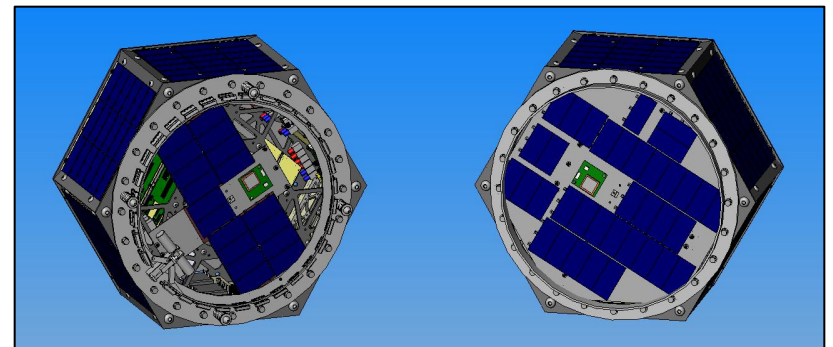
**2. Battery Box Mounted**



**5. Thruster System Mounted**



**3. Comm. System Mounted**



**6. Solar Panels Mounted**



# Clean Room

- **Design**
  - 2" PVC Pipe
  - Heavy weight clear plastic vinyl sheet
  - Entry/Exit through slits in plastic
  - Positive pressure provided by blower unit
    - Ducting routed to top of Clean Room "Tent"
    - Air passes through HEPA filter prior to entering Clean Room
- **Contamination Considerations**
  - Sticky Mat outside of Dressing Area used for removing debris from shoes
  - Dress Area used for donning clean room garments
    - Head Cap / Face Masks
    - Lab Coat
    - Gloves
    - Booties
  - User is required to don the proper garments before entering the clean room
- **ESD Considerations**
  - All flight hardware, integration tools are stored in locked, grounded Flight Hardware Storage Cabinet when not in use
  - Integration Table will serve as work area for Clean Room users
    - Electro statically isolated
    - ESD work area mat with grounding arm band
    - Grounded tile floor







# Clean Room

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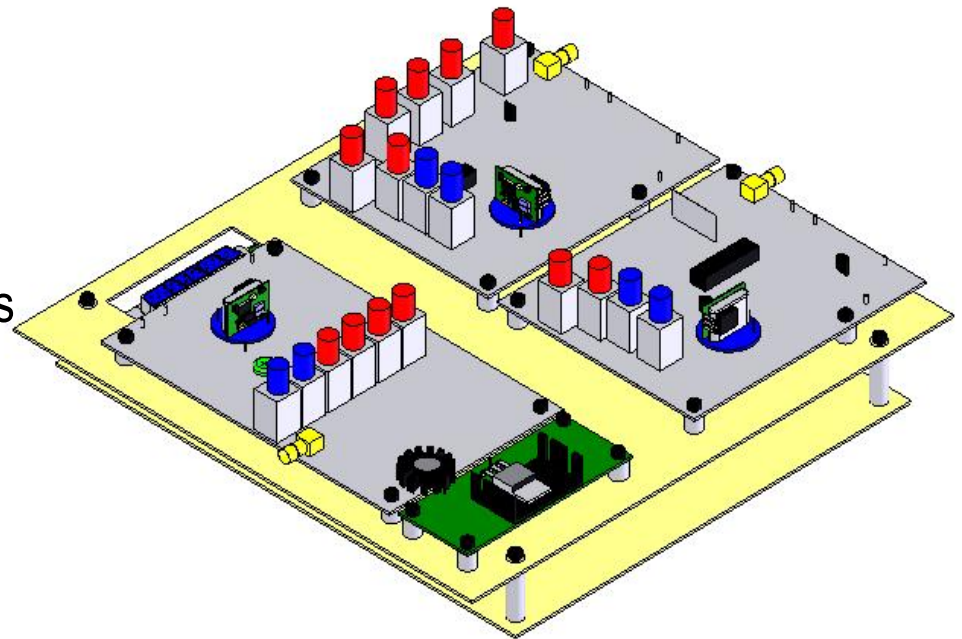






# Communications

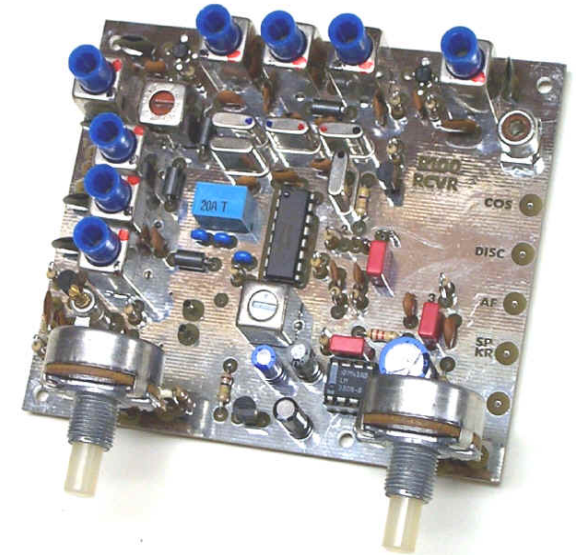
- **Requirements**
  - 144-146 MHz
    - Telemetry Uplink: 9600 / 1200 bps
  - 435-438 MHz
    - Telemetry Downlink: 9600/ 1200 bps
    - Inter-satellite Crosslink 9600 bps
    - 2 Watts TX Power
    - Secondary Uplink
- **Radio**
  - Hamtronics Transmitters and Receivers
  - Kantronics 9612+ TNC
  - Based on PCSAT2 design
- **Antennas**
  - Deployable Whip Antennas
  - Structural Locations
- **Hardware status**
  - Acquired and In Testing



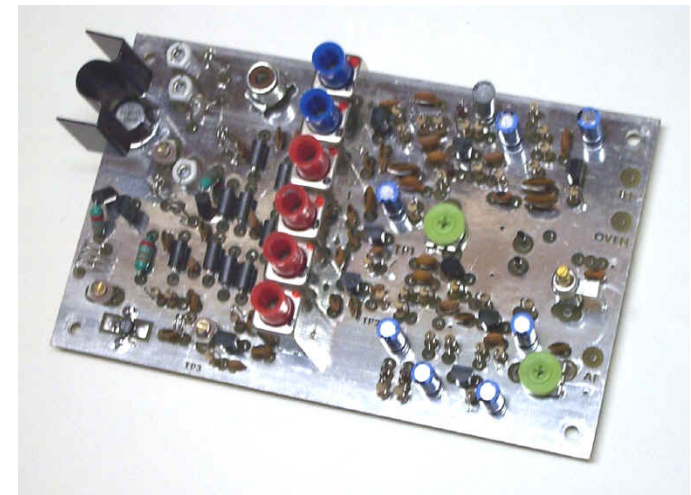


# Communications

- **Data Budget: 1KB/sample**
  - Orion: 600 bytes per sample
    - Processed Navigation Measurements: 100 bytes per sample
    - Raw Output: 500 bytes per sample
  - Housekeeping/Error Checking: 200 bytes per sample
    - Battery/Solar Panel Status
    - Magnetometer
    - Checksums
    - Encryption
  - Telemetry Re-Sends: 200 bytes per sample
  - Total Data Budget: 1000 bytes per sample
- **Dual Data Sampling Modes**
  - High Rate Mode: 30 samples per minute
    - Used during initial satellite separation
    - Downlink may require multiple ground passes
    - 1.8 MB/hour = 2.7 MB/orbit
  - Low Rate Mode: 1 sample per minute
    - Used for real-time nominal operation and post-processing
    - 60 KB/hour = 90 KB/orbit
- **Data Downlink per Ground Pass**
  - 0.864 MB/ground pass  $\approx$  850 data samples/ground pass
  - Approx. 28 minutes of high rate or 840 minutes of low rate



Hamtronics R100 Receiver

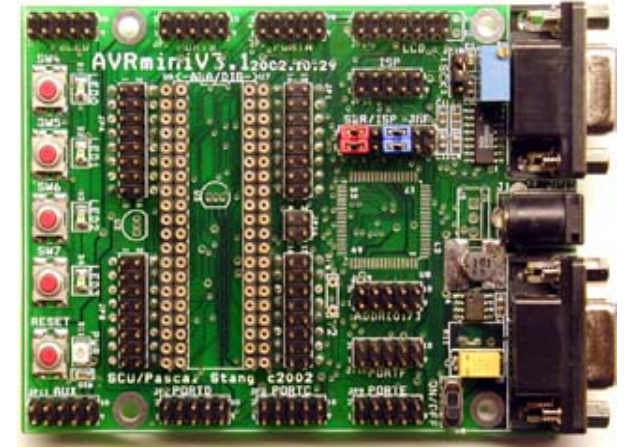
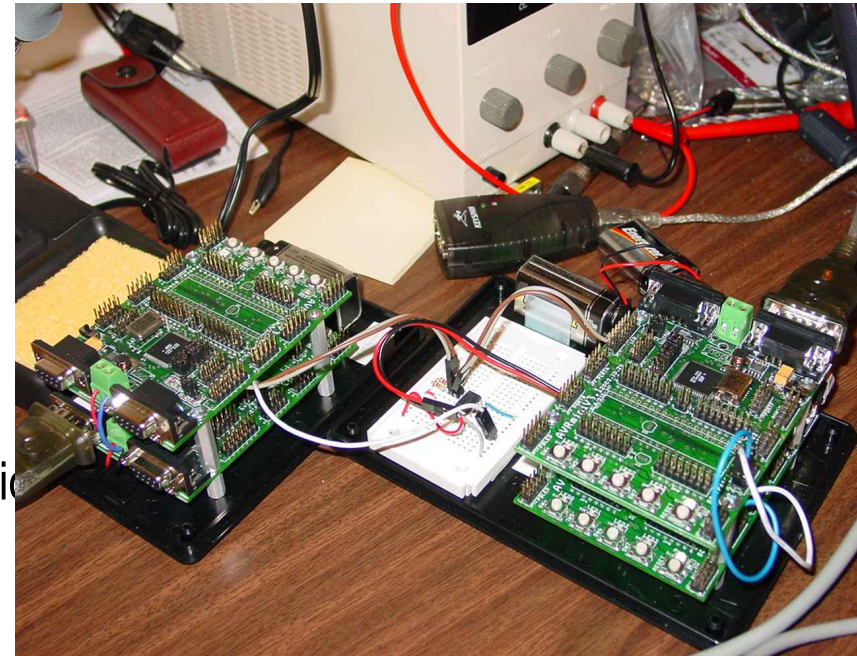


Hamtronics T451 Transmitter



# Command and Data Handling

- **Distributed Data Bus**
  - 2-wire I<sup>2</sup>C subsystem communication
  - Dallas 1-wire subsystem status monitoring
  - 5 operational subsystems
- **Subsystem Control Unit**
  - Dedicated microprocessors
  - Independent 5V and 12V over-current protection
  - 128K bit EEPROM
  - 12 channel A/D converter
- **Data Bus Harness**
  - 24 AWG wire
  - Gold, space-rated DB-9 connectors
- **Hardware Status**
  - Partially acquired, in testing

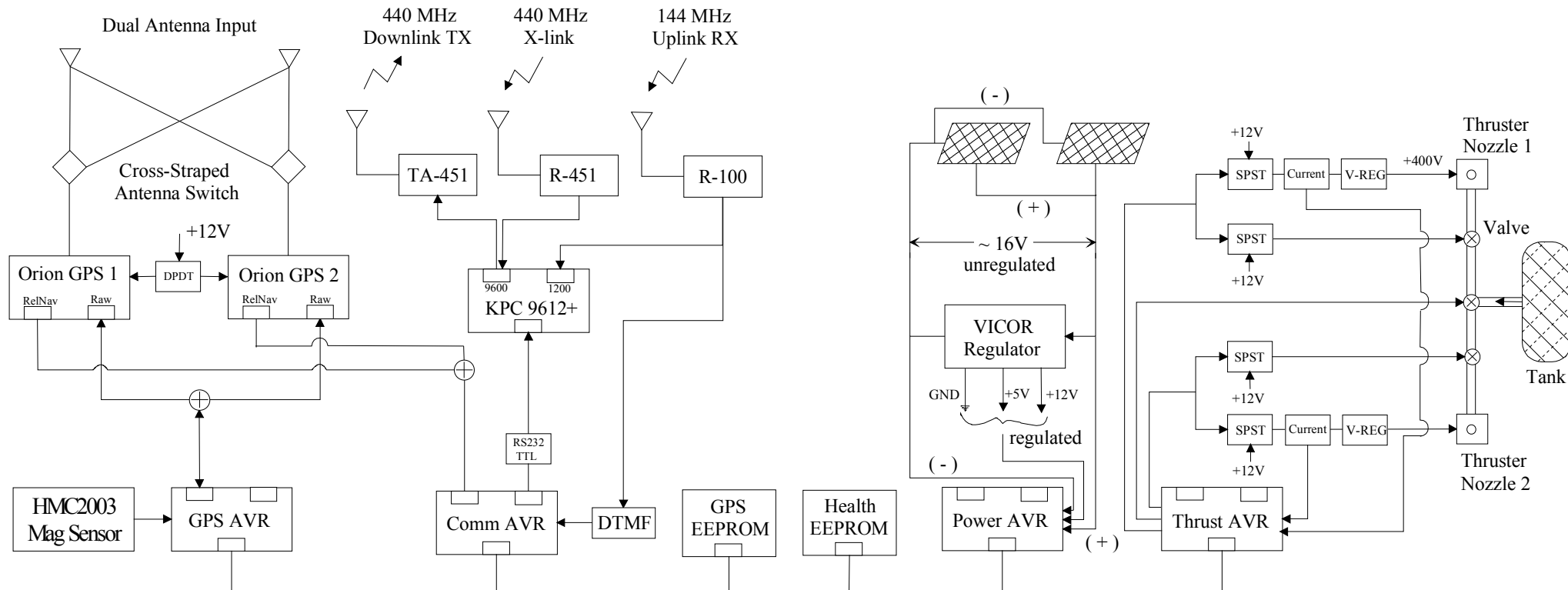


AVRmini Microcontroller Board





# Command and Data Handling

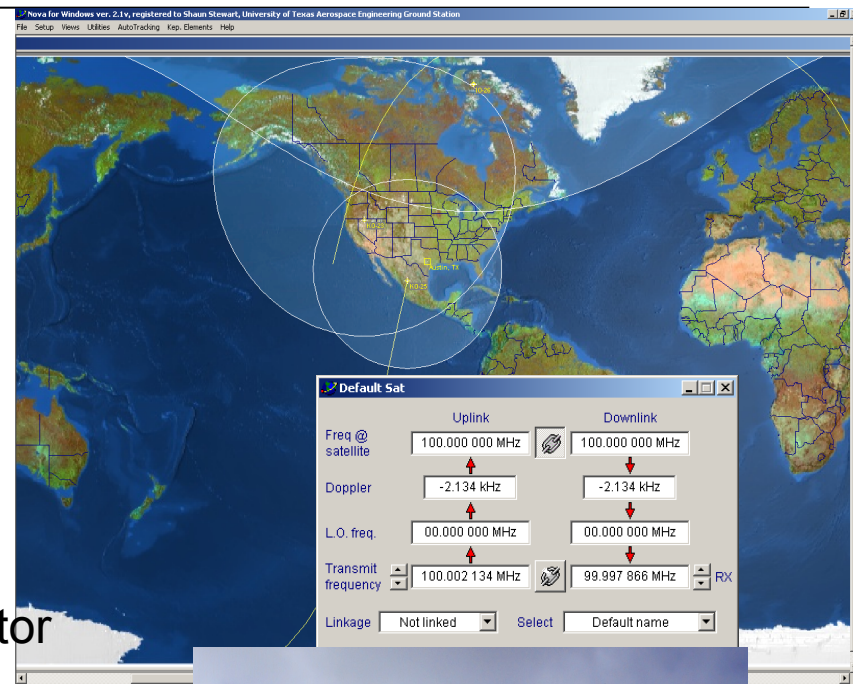




# Ground Station

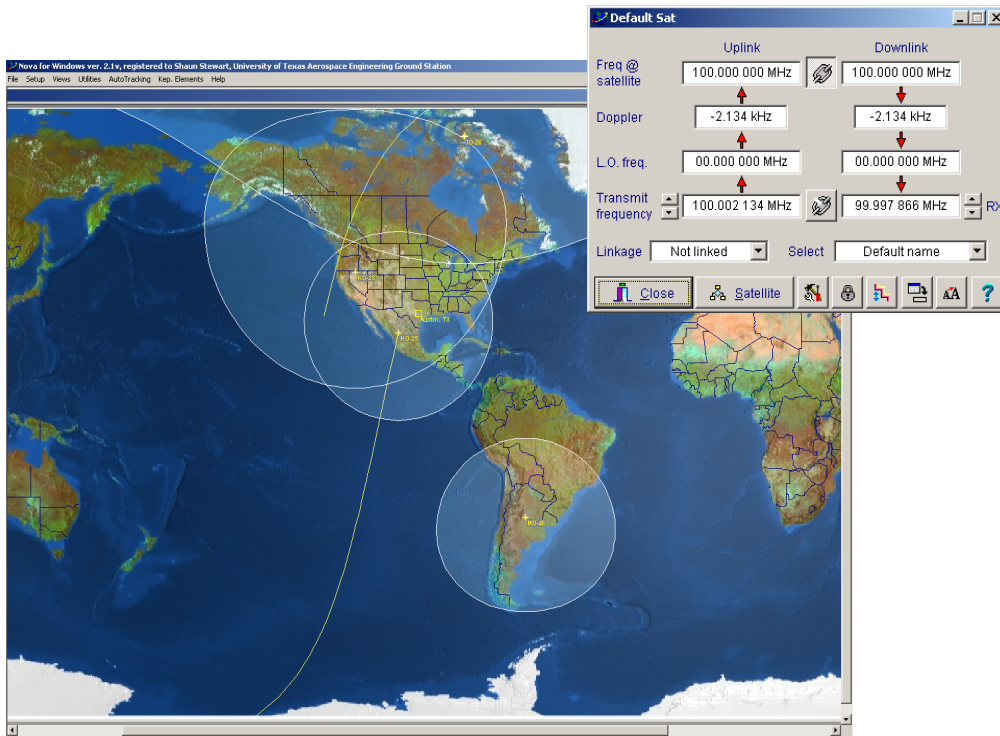
## Equipment

- 2-meter antenna M<sup>2</sup> 2M-CP 22 circularly polarized Yagi 22-element antenna.
- 70 cm antenna M<sup>2</sup> 436-CP 42 UG ultra gain circularly polarized 42-element Yagi antenna
- 2-meter preamp SSB SP-2000 low noise mast mounted gasfet preamplifier
- 70 cm preamp SSB SP-7000 low noise mast mounted gasfet preamplifier
- Crossboom M<sup>2</sup> Fiberglass
- Antenna Positioner Yaesu G-5500 Az-El combo rotor
- Coax cable Times Microwave LMR-400 low loss cable. Total run ~ 160 ft
- Transceiver ICOM 910H with matching power source
- Tranceiver interface ICOM CT-17 TTL to RS-232 converter
- Software National Instruments Labview
- TNC Kantronics KPC-9612 Plus
- Positioner Interface Labjack U-12 USB Daq and control device with Labjack Piggyback from NLSA
- Software Nova for Windows from NLSA





# Ground Station



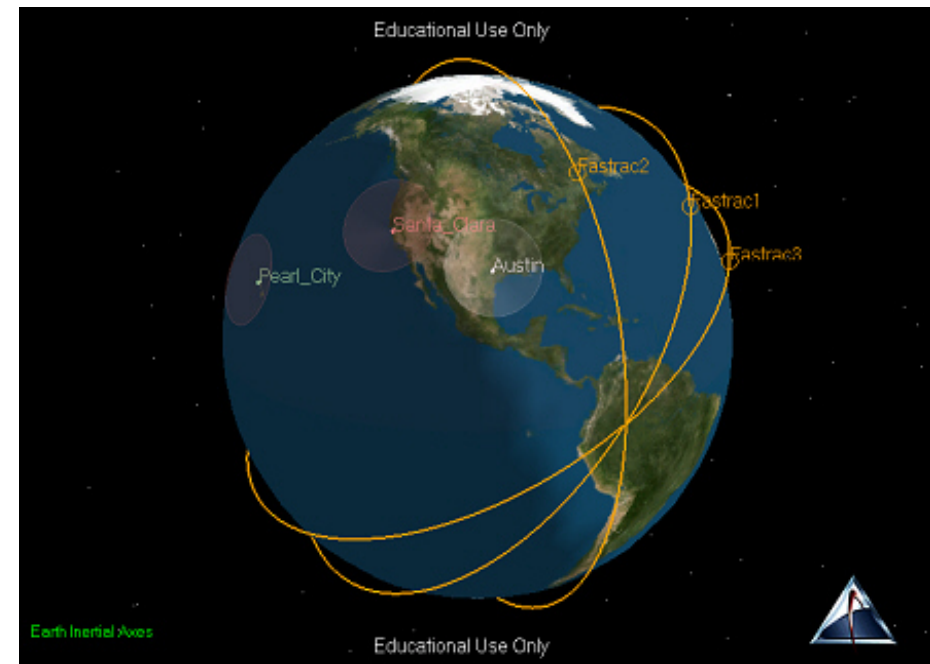
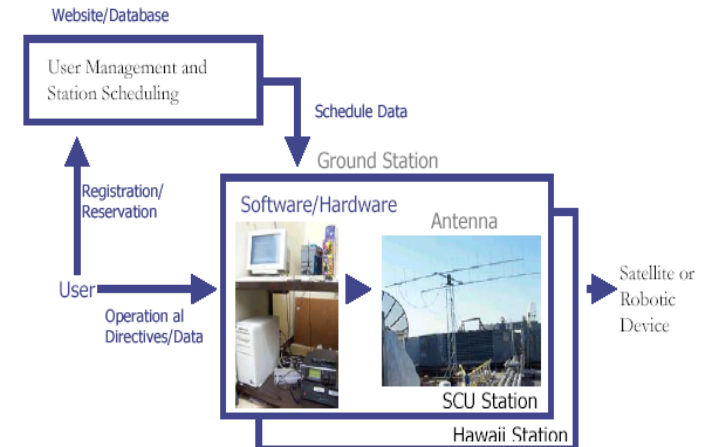
- **Future Developments**
  - 1.2/2.4 GHz Antenna 3-meter mesh dish
  - Antenna Feed Home built dual band patch with Down East Microwave Preamp and down converter
  - Positioner Deskin Research Group augmented custom robot positioning system
  - Coax cable RG-8X high loss plenum rated fireproof stuff
  - Receiver ICOM IC-R7100 and a spare
  - Receiver interface ICOM CT-17 TTL to RS-232 converter
  - Software National Instruments Labview
  - Positioner Interface NI PXI chassis with motion control module?
  - Software National Instruments Labview





# Network Distributed Ground Stations

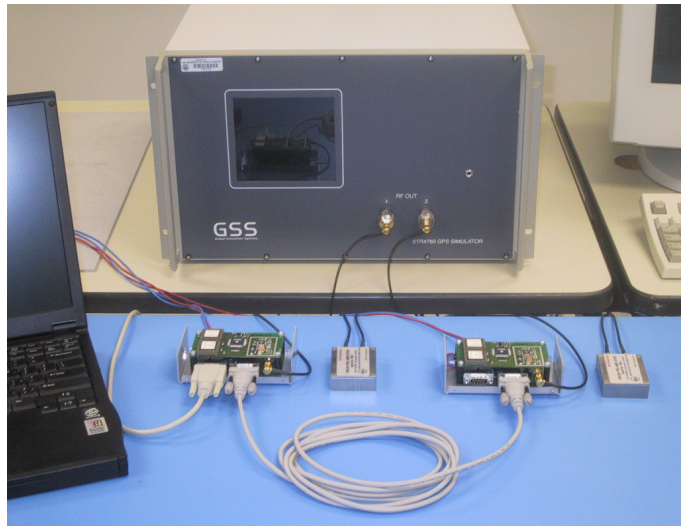
- Multiple Stations Available for Tracking
  - Demonstrate Effectiveness for Formations
- Requires Coordinated Scheduling
- Based on Santa Clara University RACE System
  - Remote Accessible Communications Environment
  - TCP/IP Comm. Standards



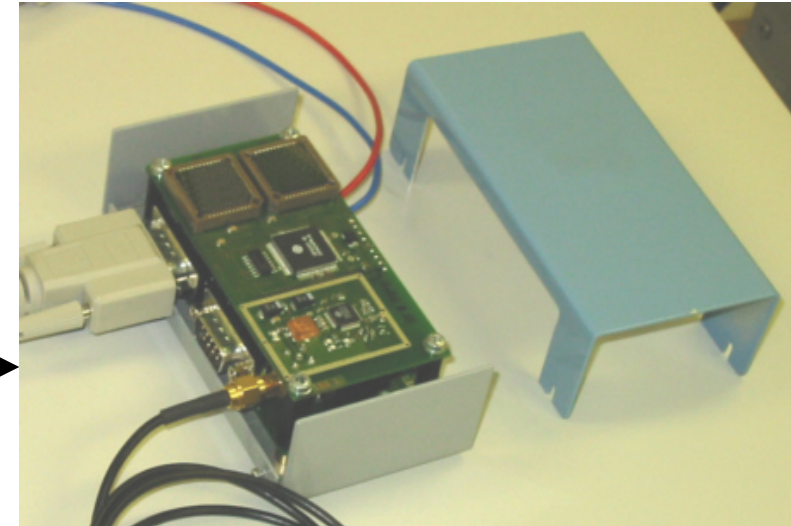


# GPS Firmware Experimental Setup and Testing

GPS Constellation Simulator



GPS Orion Receiver



Simulated RF



GPS SNR

Spacecraft  
Attitude



EKF Estimation  
Algorithm  
(post processed)

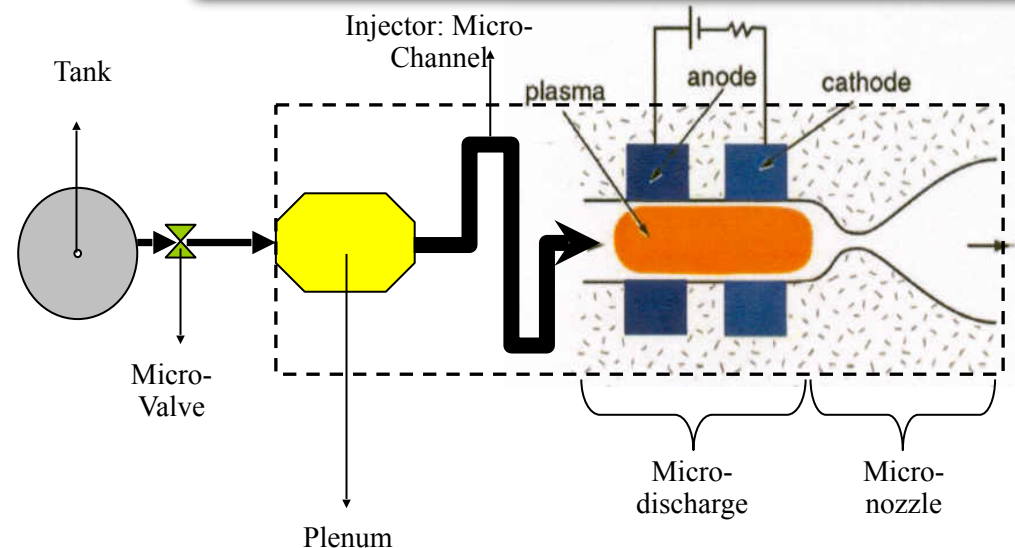
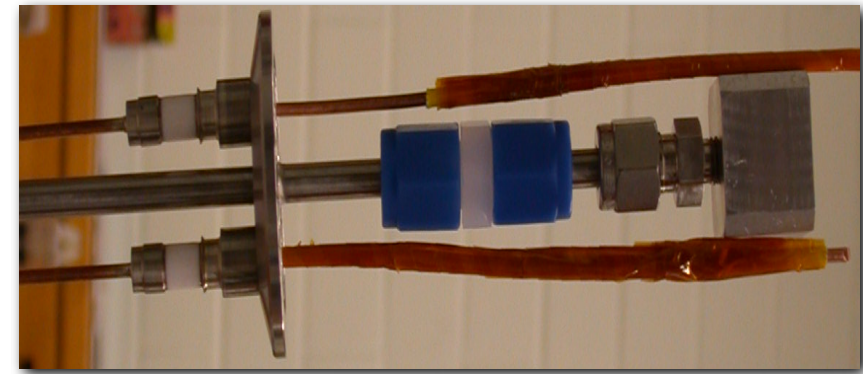
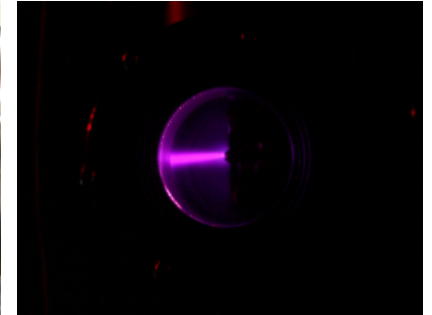
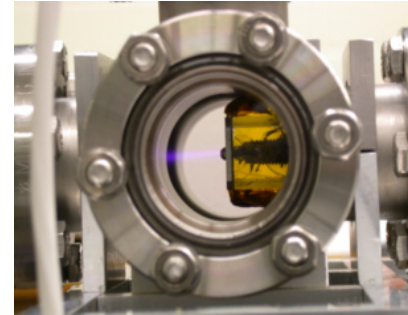
Simulated  
B-field Input





# Microdischarge Plasma Thruster

- Microdischarge creates plasma
- Mass ~2 kg
- Argon Propellant
- Voltage Requirement ~300 to 1000 V
- Size without tank ~1x1x1 cm
- Less than 2 watts of power
- MEMS Micronozzle
- 100psi Tank Pressure
- Thrust ~200 Micronewtons
- Specific Impulse ~500 seconds
- Temperature ~1000K

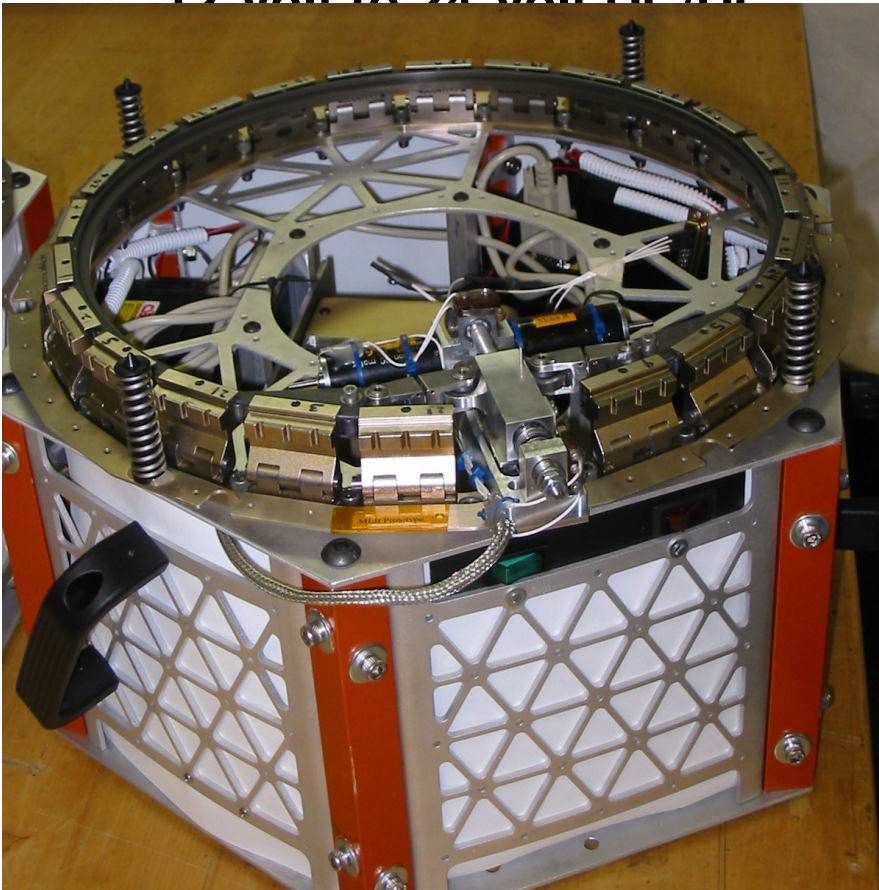




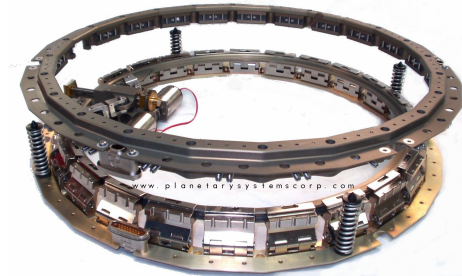


# Separation System

- Planetary Systems Corporation
  - 15-inch Motorized Lightband (MLB)
- Vicor Space Qualified Power Regulators
  - 12 Volt to 24 Volt DC/DC



KC-135 Microgravity Experiment



Motorized Lightband (MLB)

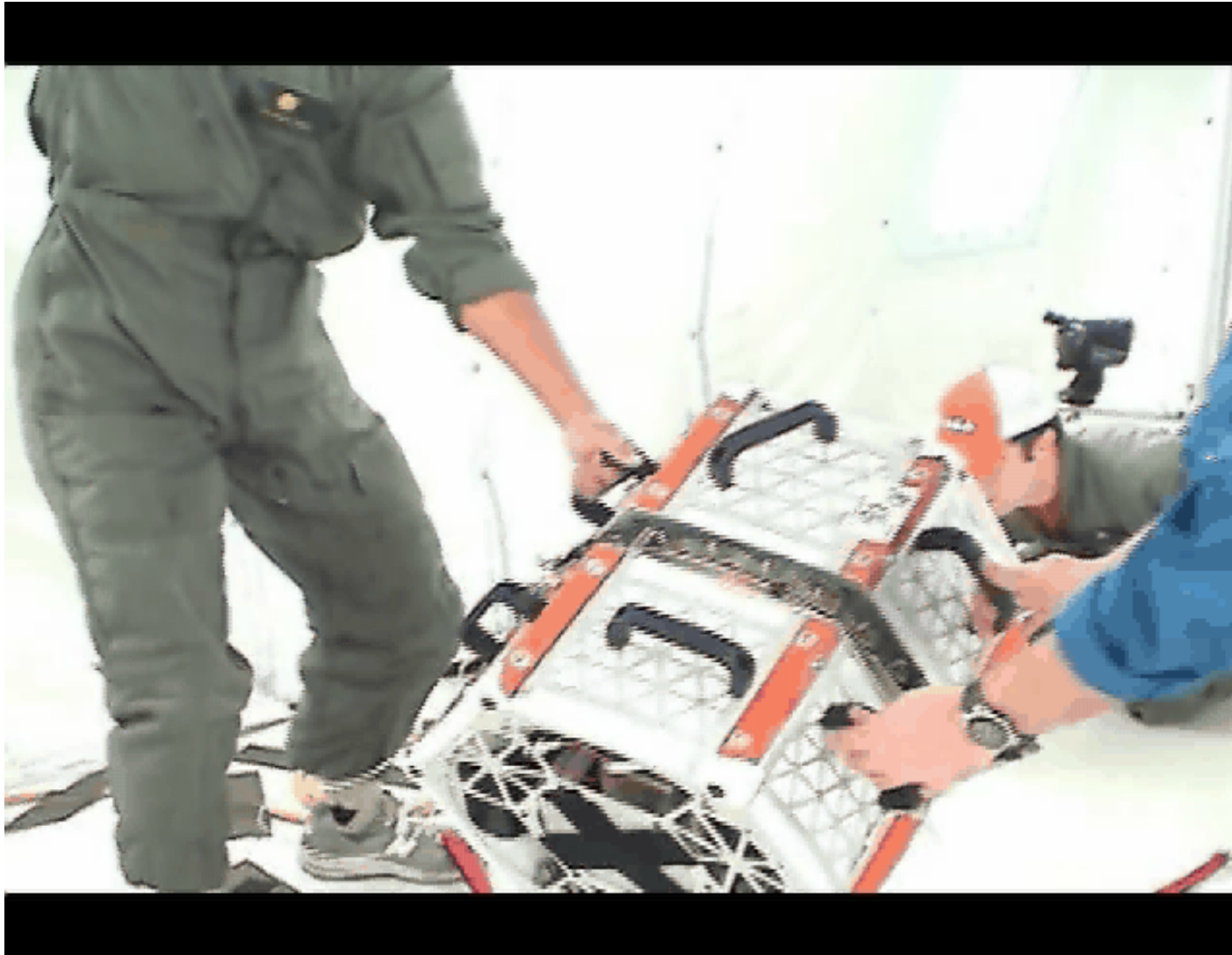


Vicor DC/DC Converter



# Separation System

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# Outreach

## Accomplishments

- Many presentations to K-12 students in Austin and Houston
- Middle school summer interns in lab
- Publications in university newsletters
- Television news stories



- <http://fastrac.ae.utexas.edu>
- Outreach to amateur radio community



